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NONPROPAGATION TEST PROGRAM FOR M55 STAB DETONATORS

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18. SUPPLEMENTARY NOTES

This program was accomplished as part of the U.S. Army's Manufacturing Methods and Technology program. The primary objective of this program is to develop, on a timely basis, manufacturing processes, techniques, and equipment for use in production of Army materiel.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Minimum nonpropagation distance
M55 Stab detonator
MMT - Ammunition

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

As part of an Army-wide expansion and modernization program, the safety of M55 detonators at various points within automated inspection equipment was studied using an MRC Corporation prototype. Test results will be used to establish safety criteria for new manufacturing LAP facilities. The program to determine the safety of the equipment was drafted by ARRADCOM and was subsequently divided into six separate phases: input/output transfer tests, intra-tray propagation tests, indexing dial spacing tests, rejected detonator container tests, indexing (cont)

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20. ABSTRACT (cont)

dial nest integrity tests, and shipping tray integrity tests.

Results of these tests indicated that:

1. A maximum of four detonators can ignite simultaneously without rupturing the outer field.

2. A minimum shield height of 50.8 mm is required for complete non-propagation between detonators within a single tray.

3. The existing machine spacing of 50.0 mm between detonators on the inspection dial is sufficient.

4. The prototype container is safe for storage of 200 to 300 detonators.

5. There was no detonator reaction upon transfer to the dial nests at transfer rates of 13.7 m/sec.

6. A safe transfer is possible when using the MRC metering valve; the setting on the valve should not exceed the 2.0 setting.

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INTRODUCTION

At the present time, an Army-wide modernization program is underway to upgrade existing installations and to develop new explosive manufacturing and LAP (Load, Assembly, Pack) facilities. This effort will enable the US Army to achieve increased production cost-effectiveness with improved safety. As a part of this overall program, the Manufacturing Technology Division, Large Caliber Weapon Systems Laboratory, ARRADCOM, Dover, New Jersey, is engaged in the development of safety criteria as an activity entitled "Safety Engineering in Support of Ammunition Plants." These criteria will be used as part of the basis for the design of explosive production installations due for modernization, including Government-owned, contractor-operated ammunition plants. The activities covered in this report provide safety data to specifically support modernization activities of the MRC Corporation in the development of the prototype Automated Inspection Equipment (AIE) for the M55 Stab Detonator.

The AIE for the M55 Stab Detonator requires a 100 percent inspection of finished stab detonators. It is configured into four identical inspection modules. The inspection equipment has a through-put requirement of 200 ppm, with each module operating at 50 ppm. The modules use an indexing dial with a nominal cycle time of one second (750 millisecond dwell). A pneumatic parts transfer method is employed for the in-feed. Since this is a new design technique, experiments of this study were conducted to determine the safety of the pneumatic transfer system.

The objective of this study was to establish the effectiveness of the planned MRC automatic detonator inspection machine and supportive conveying systems to provide suppression of accidental detonator initiations.

EXPERIMENTAL METHODS

MATERIAL

M55 Stab Detonators were received from the Lone Star Army Ammunition Plant, Lot Number LS-367-125, manufactured 3-[illegible]-80. The detonators were received packaged 50 detonators per cardboard tray, 20 trays per carton, and five cartons per wooden box.

MRC provided the dial indexing integrity test fixture and tube-to-dial interface adapter. A Deltron Fluid Products metering valve, model EFC 20, was later supplied by MRC for the indexing dial integrity test and the shipping tray integrity test.

TEST PLAN

The test program was divided into six phases: phase 1, input/output transfer tube tests; phase 2, intra-tray propagation; phase 3, indexing dial spacing; phase 4, reject detonator container; phase 5, indexing dial nest integrity tests; and phase 6, shipping tray integrity tests. Each phase is described in detail.

Phase 1: Input/Output Transfer Tests

The objective of these tests was to determine the effectiveness of the lexan® cover shield 38.1 mm OD by 32.0 mm ID by 609.6 mm long (1.5 in. x 1.26 in. x 24 in.) to contain an accidental detonator initiation within the transfer tube. A series of 50 tests were to be conducted where a single detonator was to be pneumatically propelled through an inner transfer tube [6.35 mm OD by 4.138 mm ID (0.25 in. by 0.17 in.) Poly-Flo #44P plastic tubing with 2758 kPa (400 psi) burst pressure] aligned with a second stationary detonator (acceptor) in a parallel transfer tube (figure 1). A total of 10 exploratory and 50 confirmatory tests were to be conducted. The observed results were to determine if the outer shield remained intact. A second series of tests were to be conducted employing multiple detonators in the transfer tube at the same time to determine the maximum quantity of detonators that could be initiated without rupturing the outer Lexan® shield. Once this upper unit of detonator initiations was determined, 10 confirmatory tests were to be conducted for statistical validity.

Phase 2: Intra-tray Propagation Tests

The objective of this test series was to determine potential detonations within locations of the loading and transfer trays of various designs and materials. Data were also to be provided as to the height of the Lexan® shield that is located above the transfer trays. A single aluminum pallet filled with 50 stab detonators was to have a detonator initiated from the bottom by a starter pin. A Lexan® shield 12.7 mm thick by 152.4 mm wide by 609.6 mm long (0.5 in. by 6 in. by 24 in.) was to be positioned at an initial height of 19.05 mm (0.75 in.) above the pallet (figure 2). If intra-propagation occurred, the height of the Lexan® shield was to be raised to a maximum height of 63.5 mm (2.5 in). If intra-propagation occurred at this height, the acceptor pallets, one on each side of the donor, would be tested for minimum safe separation distance between pallets. A total of 50 confirmatory tests were to be conducted in the intra-propagation configuration and 25 confirmatory tests in the inter-tray propagation configuration.

Phase 3: Indexing Dial Spacing

The objective of this test series was to determine if the proposed detonator separation of the inspection machine indexing dial was sufficient to prevent propagation of an explosive incident. The inspection machine rotates the detonators through the various inspection points on a circular indexing dial that receives and nests the detonators at the input station, and finally ejects the detonators at the output station. Within the machine, the detonators are equally spaced around the circumference of the indexing dial. MRC supplied a test fixture (figure 3) to simulate the equal spacing of the dial test fixture. An acceptor detonator was to be oriented in the same manner as the donor at a distance of 49.78 mm (1.96 in.). A firing pin was to be used to initiate the donor. Acceptance criteria was to be the non-propagation of the acceptor. A total of 50 tests (10 exploratory and 40 confirmatory) were to be conducted in this configuration.

Phase 4: Rejected Detonator Container

During the normal operation of the inspection machine, any detonator that is rejected is transferred to a separate container within the inspection machine. Whenever the quantity of rejected detonators exceeds a predetermined number, a signal is sent requiring that the reject container be emptied. The objective of these tests was to determine the structural integrity of the proposed detonator reject container and the maximum quantity of detonators in the event of initiation. The initial test series was to be conducted on the test fixture (figure 4). Varying numbers of detonators (150 to 500) were to be placed inside the reject container in a styrofoam cup and initiated with a J2 blasting cap. Static pressure and temperature measurements were to be obtained.

Phase 5: Indexing Dial Nest Integrity Tests

The inspection machine indexing dial nest receives the detonators from the transfer tube via pneumatic transfer. Maximum pressure in the event of regulator failure is 689 kPa (100 psi) and the normal transfer pressure is 345 kPa (50 psi). The transfer pressure is forced through a metering valve so that the transient time averages 325 milliseconds for a 1.22-meter (4-foot) distance. The test setup is shown in figure 5. A minimum of 50 tests (10 exploratory and 40 confirmatory) were to be conducted in this configuration.

Phase 6: Shipping Tray Integrity Tests

The objective of these tests was to determine the potential for detonator function upon insertion into a cardboard pallet. Upon completion of the inspection procedure, the machine ejects the detonators from the indexing dial nest and transfers them pneumatically, with an average transient time of approximately 300 milliseconds at an operational pressure of 345 kPa (50 psi). Again, these tests were to be conducted at a maximum allowable pressure of 689 kPa (100 psi). Acceptance test criteria was to be non-functioning when the detonators were inserted pneumatically into the shipping trays. This test configuration is shown in figure 6. A minimum of 50 tests (10 exploratory and 40 confirmatory) were to be conducted at maximum pressure.

INSTRUMENTATION

Pressure measurements for the reject detonator container were to be obtained using two strain gauge pressure transducers. A DYNISCO Model PT 119G-50 [0-3447 kPa (0-50 psi)] and an MB Electronics Model 151-15C-194 [0-1724 kPa (0-250 psi)] were attached to the reject container through a common port. The transducers were to be pneumatically calibrated prior to the beginning of each test series to correspond to the maximum output of the transducer. A Chromel/Alumel thermocouple was to be installed in the fixture to measure the reaction temperature. Instrumentation setup is shown in figure 7.

RESULTS

DATA ANALYSIS

Initally, exploratory tests were conducted in which a reversal type of reaction was obtained. That is, when the initial test setup of the series did not cause an acceptor item to function, then the item was subjected to a more severe donor reaction (i.e., closer distance) until the acceptor item was caused to function by the donor reaction. When this occurred, a distance at which there was no acceptor reaction was empirically determined. Once this distance was verified, a series of confirmatory tests were performed to provide statistical validity.

The probability of the occurrence of a propagation is dependent upon the degree of certainty or confidence level involved and has lower and upper limits. The lower limit for all confidence levels is zero, and the upper limit is a function of the number of observations of the acceptor items tested without a reaction. Each observation is independent of each of the other observations, having a constant probability of occurrence. The number of reactions (χ) in a given number of observations (n) will have a binomial distribution. The estimated probability (ρ) of a reaction occurring is represented by the expression

$$\rho = \chi/n \quad . \tag{1}$$

The expected value of χ is given by:

$$E(\chi) = n\rho \quad . \tag{2}$$

Each confidence level will have a specific upper limit (ρ_2) depending upon the number of observations involved. The upper probability limit for a given confidence level (α) where a reaction is not observed is expressed as:

$$(1 - \rho_2)^n = E \quad , \tag{3}$$

$$\text{where } E = (1 - \alpha)/2 \text{ and } \alpha < 1.0 \quad . \tag{4}$$

Fifty confirmatory tests should result in a 7.11 percent probability at a 95 percent confidence level.

TEST RESULTS

Test results are shown in tables 1 through 7; figures 8 through 13 are selected photographs of test results. Exploratory tests are noted by an (E) prefix and the confirmatory tests are denoted by a (C) prefix. If the 10 exploratory tests did not react, they were counted as part of the total confirmatory tests.

DISCUSSION

Phase 1: Input/Output Transfer Tube Tests

Test results of a single detonator with a single acceptor are given in table 1. A total of 10 exploratory and 40 confirmatory tests were conducted. The outer shield did not rupture, but a slight bulge was noticeable after every three or four initiations. The donor detonator was pneumatically transported through a 609.6-mm (24-in) plastic tube striking a firing pin; an acceptor detonator was parallel. The donor inner plastic tube would rupture at the point of initiation. The acceptor detonator would function and the acceptor inner tube would also rupture. In 12 of the 50 tests, the acceptor detonator did not function. This was caused by blow-back pressure when the donor detonator was being transported. The outer shield was effective in preventing fragmentation when a single donor detonator and a single acceptor detonator were simultaneously ignited.

Table 2 shows results of the multiple detonator transport tests. When three donors and three acceptors were initiated, a small hole 6.35 mm (0.25 in.) in diameter was made in the outer shield. Figures 8, 9, and 10 show visible results of these tests. The diameter of the hole increased with each successive test when additional acceptor and donor detonators were added. The exploratory tests using five donor and five acceptor detonators resulted in a 25.4 mm (1 in.) hole in the Lexan® tube. Since the outer shield tubing was not defeated using two donor and two acceptor detonations, the confirmatory tests were conducted in this configuration. There was no rupture of the outer shield but there was noticeable bulging.

Phase 2: Intra-Tray Propagation Test

Table 3 depicts the results of these tests. The initial exploratory and confirmatory tests were conducted at a height of 19.05 mm (0.75 in). However, at test number C23 there was complete detonation of all 50 stab detonators. The Lexan® shield was shattered and the test fixture was damaged. The damage is shown in figures 11, 12, and 13. Based upon the test results, the height of the shield was raised to 38.1 mm (1.5 in). Propagation of two detonators occurred on test number 11. Neither acceptor detonator was adjacent to the donor. The height of the shield was raised to 50.8 mm (2 in) and 50 confirmatory tests were conducted without incident. Because intra-propagation did not occur at this height [50.8 mm (2 in)], the multi-tray tests were not conducted.

Phase 3: Indexing Dial Spacing

A total of 10 exploratory and 40 confirmatory tests were conducted. There was no propagation between donor and acceptor. However, the test fixture supplied by MRC had to be refurbished after six to ten tests due to the damage by the donor reaction. On tests E4, C1, C2, and C6 the acceptor had evidence of flash burns from the donor reaction. The test results are shown in table 4.

Phase 4: Rejected Detonator Container

Test results are given in table 5. The initial test series consisted of three tests, each with 200 stab detonators in the reject container. The average pressure was 2523 kPa (366 psi) and the average temperature was 150°C. There was no failure of the pressure vessel. A test consisting of 300 stab detonators resulted in a measured pressure value of 2889 kPa (419 psi) and a temperature measurement of 173°C. The 500 stab detonator test caused no failure of the pressure vessel, but there was violent eruption around the flange. The pressure measurement was 3378 kPa (490 psi) and the temperature was 196°C. A single test was conducted at the 400 detonator level and the vessel reaction was less violent. The maximum pressure was 2841 kPa (412 psi) and the maximum temperature was 177°C.

A note of caution should be taken in that the reject detonator container used for these tests was a completely closed vessel, whereas the actual vessel in the MRC inspection stations has an entry port where the rejected detonators must enter. The actual reject container, then, would vent the expanding gases.

Phase 5: Indexing Dial Nest Integrity Test

A total of seven exploratory tests were conducted varying the metering value setting from 5 to 1.5. This represents a transfer rate between 13.7 m/sec to 6 m/sec (85 ft/sec to 20 ft/sec) respectively. There were no reactions at any setting using 689 kPa (100 psi). A value setting of 1.5 with a transfer rate of 6 m/sec (20 ft/sec) was similar to the transfer rate used by MRC; therefore, the 50 confirmatory tests were conducted at this setting. Test results are given in table 6.

Phase 6: Shipping Tray Integrity Test

A total of 36 exploratory and 50 confirmatory tests were conducted and the results are given in table 7. Initially, the stab detonators reacted when transported at both 690 kPa and 345 kPa (100 psi and 50 psi). Testing was conducted on this test series until a metering valve was supplied by MRC. The tests were then repeated utilizing different settings. The final setting on the metering value was 2.0 as the stab detonators had reacted at settings from 5 to 3. Another difficulty noticed was that the donor would not always seat into the pallet correctly. Once a proper valve setting was established, 50 confirmatory tests were conducted without incident. However, the metering valve setting is critical.

CONCLUSIONS

The results of the input/output transfer tube tests determined that an outer shield constructed of Lexan® tubing 38.1 mm (1.5 in) OD by 32.0 mm (1.26 in) ID is effective when two donors and two acceptors in adjacent inner plastic tubes ignite simultaneously. Therefore, a maximum number of four detonators can ignite simultaneously without rupturing the outer shield.

Intra-tray propagation can occur when a single detonator is initiated. The minimum shield height to prevent intra-tray propagation is established as 50.8 mm (2 in) above the tray surface.

The MRC spacing of 50 mm between detonators on the inspection dial is sufficient to preclude propagation in the event of an accidental initiation.

The results of the rejected detonator container tests indicate that a maximum of 300 detonators is the upper limit to preclude serious damage to inspection machinery.

The results of the indexing dial test indicate that there is no detonator reaction upon transfer to the dial nest at transfer rates up to 13.7 m/sec. However, the metering valve setting is critical.

The results of the shipping tray integrity tests indicate that a safe transfer is possible when using the MRC metering valve, and the setting on the valve should not exceed the number 2.0 setting.

RECOMMENDATIONS

Based upon the test results, it is recommended that the findings of this report should be considered in the design, acceptance, and operation of the MRC Automated Inspection Equipment for M55 Stab Detonators.

Table 1. Input/output transfer tube results

Test number	Temperature		Humidity	Pressure		Donor reaction		Acceptor reaction		Shield rupture		Remarks
	°C	(°F)	%	kPa	(psi)	Yes	No	Yes	No	Yes	No	
E1	21.1	(70)	50	276	(40)	X		X			X	
E2	21.7	(71)	49	276	(40)	X		X			X	
E3	22.2	(72)	49	276	(40)	X		X			X	
E4	22.2	(72)	48	276	(40)	X			X		X	
E5	22.2	(72)	48	276	(40)	X		X			X	
E6	20.0	(68)	53	276	(40)	X			X		X	
E7	20.6	(69)	52	276	(40)	X		X			X	
E8	22.8	(73)	50	345	(50)	X		X			X	
E9	23.9	(75)	49	345	(50)	X			X		X	
E10	25.0	(77)	42	345	(50)	X		X			X	
C1	25.6	(78)	42	345	(50)	X			X		X	
C2	25.6	(78)	42	345	(50)	X		X			X	
C3	22.2	(72)	46	345	(50)	X		X			X	
C4	22.2	(72)	46	345	(50)	X		X			X	
C5	22.2	(72)	46	345	(50)	X		X			X	
C6	22.2	(72)	46	345	(50)	X		X			X	
C7	22.2	(72)	46	345	(50)	X		X			X	
C8	22.2	(72)	46	345	(50)	X			X		X	
C9	13.9	(57)	50	345	(50)	X		X			X	
C10	13.9	(57)	50	345	(50)	X		X			X	
C11	13.9	(57)	50	345	(50)	X		X			X	
C12	13.9	(57)	50	345	(50)	X			X		X	
C13	13.9	(57)	50	345	(50)	X		X			X	
C14	19.4	(67)	45	345	(50)	X			X		X	
C15	19.4	(67)	45	345	(50)	X		X			X	
C16	19.4	(67)	45	345	(50)	X		X			X	
C17	19.4	(67)	45	345	(50)	X		X			X	
C18	19.4	(67)	45	345	(50)	X		X			X	
C19	19.4	(67)	45	345	(50)	X		X			X	
C20	19.4	(67)	45	345	(50)	X			X		X	
C21	22.2	(72)	42	345	(50)	X			X		X	
C22	22.2	(72)	42	345	(50)	X		X			X	
C23	22.2	(72)	42	345	(50)	X		X			X	
C24	22.2	(72)	42	345	(50)	X			X		X	
C25	22.2	(72)	42	345	(50)	X		X			X	
C26	22.2	(72)	54	345	(50)	X		X			X	
C27	22.2	(72)	54	345	(50)	X		X			X	
C28	22.2	(72)	54	345	(50)	X		X			X	
C29	22.2	(72)	54	345	(50)	X		X			X	
C30	22.2	(72)	54	345	(50)	X		X			X	
C31	18.3	(65)	46	345	(50)	X			X		X	
C32	18.3	(65)	46	345	(50)	X		X			X	
C33	18.3	(65)	46	345	(50)	X		X			X	
C34	18.3	(65)	46	345	(50)	X		X			X	
C35	18.3	(65)	46	345	(50)	X			X		X	
C36	18.3	(65)	46	345	(50)	X		X			X	
C37	18.3	(65)	46	345	(50)	X		X			X	
C38	18.3	(65)	46	345	(50)	X		X			X	
C39	18.3	(65)	46	345	(50)	X		X			X	
C40	18.3	(65)	46	345	(50)	X		X			X	

Table 2. Multiple detonator in input/output transfer tube test results

Test number	Number of donor/acceptor	Temperature °C	Temperature (°F)	Humidity %	Pressure kPa	Pressure (psi)	Donor reaction Yes	Donor reaction No	Acceptor reaction Yes	Acceptor reaction No	Shield rupture Yes	Shield rupture No	Remarks
E1	2/2	18.3	(65)	45	345	(50)	X		X			X	Bulge in outer shield
E2	3/3	23.3	(74)	42	345	(50)	X		X		X		0.25" diameter hole in outer shield
E3	4/4	23.3	(74)	42	345	(50)	X		X		X		0.5" diameter hole in outer shield
E5	5/5	23.3	(74)	42	345	(50)	X		X		X		1" diameter hole in outer shield
C1	2/2	18.3	(65)	45	345	(50)	X		X			X	Bulge in outer shield
C2	2/2	18.3	(65)	45	345	(50)	X		X			X	Bulge in outer shield
C3	2/2	18.3	(65)	45	345	(50)	X		X			X	Bulge in outer shield
C4	2/2	23.3	(74)	42	345	(50)	X		X			X	Bulge in outer shield
C5	2/2	23.3	(74)	42	345	(50)	X		X			X	Bulge in outer shield
C6	2/2	23.3	(74)	42	345	(50)	X		X			X	Bulge in outer shield
C7	2/2	23.3	(74)	42	345	(50)	X		X			X	Bulge in outer shield
C8	2/2	23.3	(74)	42	345	(50)	X		X			X	Bulge in outer shield
C9	2/2	23.3	(74)	42	345	(50)	X		X			X	Bulge in outer shield
C10	2/2	23.3	(74)	50	345	(50)	X		X			X	Bulge in outer shield

Table 3. Intra-tray propagation test results

Test number	Temperature °C	Temperature (°F)	Humidity %	Donor index number	Height mm	Height (in)	Donor reaction Yes	Donor reaction No	Intra-propagation Yes	Intra-propagation No	Remarks
E1	26.1	(79)	49	24	19.05	(0.75)	X			X	
E2	26.7	(80)	49	24	19.05	(0.75)	X			X	
E3	26.7	(80)	49	23	19.05	(0.75)	X			X	
E4	26.7	(80)	48	22	19.05	(0.75)	X			X	
E5	20.0	(68)	34	22	19.05	(0.75)	X			X	
E6	20.0	(68)	34	23	19.05	(0.75)	X			X	
E7	20.0	(68)	34	28	19.05	(0.75)	X			X	
E8	20.0	(68)	34	23	19.05	(0.75)	X			X	
E9	20.0	(68)	34	28	19.05	(0.75)	X			X	
E10	20.0	(68)	34	23	19.05	(0.75)	X			X	
C1	20.0	(68)	34	23	19.05	(0.75)	X			X	
C2	21.1	(70)	34	18	19.05	(0.75)	X			X	
C3	21.1	(70)	47	19	19.05	(0.75)	X			X	
C4	22.2	(72)	35	23	19.05	(0.75)	X			X	
C5	22.2	(72)	35	24	19.05	(0.75)	X			X	
C6	22.2	(72)	35	27	19.05	(0.75)	X			X	
C7	22.2	(72)	35	29	19.05	(0.75)	X			X	
C8	22.2	(72)	35	30	19.05	(0.75)	X			X	
C9	22.2	(72)	35	32	19.05	(0.75)	X			X	
C10	22.2	(72)	35	33	19.05	(0.75)	X			X	
C11	22.2	(72)	35	34	19.05	(0.75)	X			X	
C12	22.2	(72)	35	12	19.05	(0.75)	X			X	
C13	22.2	(72)	35	13	19.05	(0.75)	X			X	
C14	22.2	(72)	35	14	19.05	(0.75)	X			X	
C15	22.2	(72)	35	29	19.05	(0.75)	X			X	
C16	22.2	(72)	35	28	19.05	(0.75)	X			X	
C17	22.2	(72)	35	27	19.05	(0.75)	X			X	
C18	22.2	(72)	35	24	19.05	(0.75)	X			X	
C19	22.2	(72)	35	23	19.05	(0.75)	X			X	
C20	22.2	(72)	35	22	19.05	(0.75)	X			X	
C21	22.2	(72)	35	32	19.05	(0.75)	X			X	
C22	22.2	(72)	35	33	19.05	(0.75)	X			X	
C23	20.6	(69)	70	29	19.05	(0.75)	X		X		**Complete tray detonated: Lexan® shield destroyed**
D1	22.2	(72)	68	23	38.1	(1.5)	X			X	
D2	22.2	(72)	68	28	38.1	(1.5)	X			X	
D3	22.2	(72)	68	23	38.1	(1.5)	X			X	
D4	22.2	(72)	85	19	38.1	(1.5)	X			X	
D5	22.2	(72)	85	22	38.1	(1.5)	X			X	
D6	22.2	(72)	85	28	38.1	(1.5)	X			X	
D7	22.2	(72)	85	19	38.1	(1.5)	X			X	
D8	22.2	(72)	85	17	38.1	(1.5)	X			X	
D9	22.2	(72)	85	12	38.1	(1.5)	X			X	
D10	22.2	(72)	85	13	38.1	(1.5)	X			X	
D11	25.6	(78)	74	14	38.1	(1.5)	X		X		**#16 and 35 acceptor detonators reacted**
A1	26.7	(80)	80	29	50.8	(2.0)	X			X	
A2	26.7	(80)	80	24	50.8	(2.0)	X			X	
A3	27.8	(82)	80	19	50.8	(2.0)	X			X	
A4	27.8	(82)	79	29	50.8	(2.0)	X			X	

Table 3. Intra-tray propagation test results (cont)

Test number	Temperature °C	Temperature (°F)	Humidity %	Donor index number	Height mm	Height (in)	Donor reaction Yes	Donor reaction No	Intra-propagation Yes	Intra-propagation No	Remarks
A5	27.8	(82)	79	22	50.8	(2.0)	X			X	
A6	27.8	(82)	79	24	50.8	(2.0)	X			X	
A7	27.8	(82)	79	22	50.8	(2.0)	X			X	
A8	27.8	(82)	79	17	50.8	(2.0)	X			X	
A9	31.1	(88)	65	28	50.8	(2.0)	X			X	
A10	31.1	(88)	65	27	50.8	(2.0)	X			X	
A11	31.1	(88)	65	29	50.8	(2.0)	X			X	
A12	31.1	(88)	65	17	50.8	(2.0)	X			X	
A13	31.1	(88)	65	19	50.8	(2.0)	X			X	
A14	31.1	(88)	65	13	50.8	(2.0)	X			X	
A15	31.1	(88)	60	14	50.8	(2.0)	X			X	
A16	31.1	(88)	60	12	50.8	(2.0)	X			X	
A17	31.1	(88)	60	17	50.8	(2.0)	X			X	
A18	31.1	(88)	60	33	50.8	(2.0)	X			X	
A19	29.4	(85)	60	32	50.8	(2.0)	X			X	
A20	29.4	(85)	60	34	50.8	(2.0)	X			X	
A21	27.8	(82)	56	37	50.8	(2.0)	X			X	
A22	26.7	(80)	55	39	50.8	(2.0)	X			X	
A23	26.7	(80)	55	32	50.8	(2.0)	X			X	
A24	26.7	(80)	55	33	50.8	(2.0)	X			X	
A25	26.7	(80)	55	32	50.8	(2.0)	X			X	
A26	23.9	(75)	65	34	50.8	(2.0)	X			X	
A27	23.9	(75)	65	33	50.8	(2.0)	X			X	
A28	23.9	(75)	65	32	50.8	(2.0)	X			X	
A29	23.9	(75)	65	29	50.8	(2.0)	X			X	
A30	23.9	(75)	65	27	50.8	(2.0)	X			X	
A31	23.9	(75)	65	24	50.8	(2.0)	X			X	
A32	23.9	(75)	65	38	50.8	(2.0)	X			X	
A33	23.9	(75)	65	34	50.8	(2.0)	X			X	
A34	23.9	(75)	65	38	50.8	(2.0)	X			X	
A35	26.7	(80)	55	18	50.8	(2.0)	X			X	
A36	26.7	(80)	55	23	50.8	(2.0)	X			X	
A37	26.7	(80)	55	28	50.8	(2.0)	X			X	
A38	26.7	(80)	55	23	50.8	(2.0)	X			X	
A39	26.7	(80)	55	32	50.8	(2.0)	X			X	
A40	26.7	(80)	55	28	50.8	(2.0)	X			X	
A41	26.7	(80)	55	27	50.8	(2.0)	X			X	
A42	26.7	(80)	55	18	50.8	(2.0)	X			X	
A43	26.7	(80)	55	17	50.8	(2.0)	X			X	
A44	26.7	(80)	55	19	50.8	(2.0)	X			X	
A45	26.7	(80)	55	28	50.8	(2.0)	X			X	
A46	26.7	(80)	55	17	50.8	(2.0)	X			X	
A47	26.7	(80)	55	28	50.8	(2.0)	X			X	
A48	26.7	(80)	55	24	50.8	(2.0)	X			X	
A49	26.7	(80)	55	34	50.8	(2.0)	X			X	
A50	26.7	(80)	55	38	50.8	(2.0)	X			X	

Table 4. Phase 3, indexing dial spacing test results

Test number	Temperature °C	Temperature (°F)	Humidity %	Donor reaction Yes	Donor reaction No	Acceptor reaction Yes	Acceptor reaction No	Remarks
E1	25.0	(77)	42	X			X	Acceptor round shifted in position
E2	25.0	(77)	43	X			X	Acceptor round blown from fixture
E3	25.6	(78)	44	X			X	
E4	25.6	(78)	44	X			X	Acceptor has flash mark from donor
E5	25.6	(78)	44	X			X	
E6	20.6	(69)	53	X			X	
E7	21.1	(70)	51	X			X	
E8	21.7	(71)	52	X			X	
E9	20.0	(68)	70	X			X	Refurbish fixture new firing pin
E10	20.0	(68)	70	X			X	
C1	20.0	(68)	70	X			X	Acceptor has flash burns from donor
C2	20.0	(68)	70	X			X	Acceptor has flash burns
C3	20.0	(68)	70	X			X	
C4	20.0	(68)	70	X			X	
C5	20.0	(68)	70	X			X	Refurbish test fixture
C6	20.0	(68)	70	X			X	Acceptor has flash burns
C7	20.0	(68)	70	X			X	
C8	20.0	(68)	70	X			X	
C9	20.0	(68)	70	X			X	
C10	20.0	(68)	70	X			X	
C11	20.0	(68)	70	X			X	
C12	23.9	(75)	70	X			X	Refurbish test fixture
C13	23.9	(75)	44	X			X	
C14	23.9	(75)	44	X			X	
C15	23.9	(75)	44	X			X	
C16	23.9	(75)	44	X			X	
C17	23.9	(75)	44	X			X	
C18	23.9	(75)	44	X			X	Refurbish test fixture
C19	15.0	(59)	54	X			X	
C20	15.0	(59)	54	X			X	
C21	15.0	(59)	54	X			X	
C22	15.0	(59)	54	X			X	
C23	15.0	(59)	54	X			X	
C24	15.0	(59)	54	X			X	
C25	15.0	(59)	54	X			X	
C26	15.0	(59)	54	X			X	
C27	16.7	(62)	54	X			X	
C28	16.7	(62)	54	X			X	
C29	16.7	(62)	54	X			X	
C30	16.7	(62)	54	X			X	Refurbish test fixture
C31	16.7	(62)	54	X			X	
C32	16.7	(62)	54	X			X	
C33	16.7	(62)	54	X			X	
C34	16.7	(62)	54	X			X	
C35	16.7	(62)	54	X			X	
C36	16.7	(62)	54	X			X	
C37	16.7	(62)	54	X			X	
C38	16.7	(62)	54	X			X	
C39	16.7	(62)	54	X			X	
C40	16.7	(62)	54	X			X	

Table 5. Phase 4, test results for rejected detonator container

Test number	Number of detonators	Pressure kPa	Pressure (psi)	Temperature °C	Temperature (°F)	Remarks
1	200	2668	(387)	156	(312.8)	Reaction self contained
2	200	2441	(354)	149	(300.2)	Leak at flange
3	200	2468	(358)	144	(291.2)	Pressure vessel held
4	300	2889	(419)	173	(343.4)	Pressure vessel held
5	400	3130	(454)	177	(350.6)	Slight pressure vent through flange
6	500	3413	(495)	196	(384.8)	Violent venting around flange area

Table 6. Indexing dial and nesting test results

Test number	Temperature		Humidity	Transfer pressure		Metering Valve Setting	Donor reaction		Detonator aligned		Remarks
	°C	(°F)	%	kPa	(psi)		Yes	No	Yes	No	
E1	22.2	(72)	56	689	(100)	2.0		X	X		Txfr rate is 25 ft/sec
E2	22.2	(72)	56	689	(100)	2.5		X	X		Txfr rate is 27 ft/sec
E3	22.2	(72)	55	689	(100)	3.0		X	X		Txfr rate is 30 ft/sec
E4	22.2	(72)	55	689	(100)	3.5		X	X		Txfr rate is 35 ft/sec
E5	22.2	(72)	55	689	(100)	4.0		X	X		Txfr rate is 38 ft/sec
E6	22.2	(72)	55	689	(100)	4.5		X	X		Txfr rate is 40 ft/sec
E7	22.2	(72)	55	689	(100)	5.0		X	X		Txfr rate is 45 ft/sec
C1	22.8	(73)	55	689	(100)	1.5		X	X		Txfr rate is 20 ft/sec
C2	22.8	(73)	55	689	(100)	1.5		X	X		Less scaring of plastic tube
C3	22.8	(73)	55	689	(100)	1.5		X	X		
C4	22.8	(73)	55	689	(100)	1.5		X	X		
C5	22.8	(73)	55	689	(100)	1.5		X	X		
C6	23.3	(74)	52	689	(100)	1.5		X	X		
C7	23.3	(74)	52	689	(100)	1.5		X	X		
C8	23.3	(74)	52	689	(100)	1.5		X	X		
C9	23.3	(74)	52	689	(100)	1.5		X	X		
C10	23.3	(74)	52	689	(100)	1.5		X	X		
C11	23.3	(74)	52	689	(100)	1.5		X	X		
C12	23.3	(74)	52	689	(100)	1.5		X	X		
C13	23.3	(74)	52	689	(100)	1.5		X	X		
C14	23.3	(74)	52	689	(100)	1.5		X	X		
C15	23.3	(74)	52	689	(100)	1.5		X	X		
C16	23.3	(74)	51	689	(100)	1.5		X	X		
C17	23.3	(74)	51	689	(100)	1.5		X	X		
C18	23.3	(74)	50	689	(100)	1.5		X	X		
C19	23.3	(74)	50	689	(100)	1.5		X	X		
C20	23.3	(74)	50	689	(100)	1.5		X	X		
C21	23.3	(74)	50	689	(100)	1.5		X	X		
C22	23.9	(75)	50	689	(100)	1.5		X	X		
C23	23.9	(75)	50	689	(100)	1.5		X	X		
C24	23.9	(75)	50	689	(100)	1.5		X	X		
C25	23.9	(75)	50	689	(100)	1.5		X	X		
C26	23.9	(75)	50	689	(100)	1.5		X	X		
C27	23.9	(75)	50	689	(100)	1.5		X	X		
C28	23.9	(75)	50	689	(100)	1.5		X	X		
C29	24.4	(76)	49	689	(100)	1.5		X	X		
C30	24.4	(76)	49	689	(100)	1.5		X	X		
C31	24.4	(76)	50	689	(100)	1.5		X	X		
C32	24.4	(76)	50	689	(100)	1.5		X	X		
C33	24.4	(76)	50	689	(100)	1.5		X	X		
C34	24.4	(76)	50	689	(100)	1.5		X	X		
C35	24.4	(76)	50	689	(100)	1.5		X	X		
C36	24.4	(76)	50	689	(100)	1.5		X	X		
C37	24.4	(76)	53	689	(100)	1.5		X	X		
C38	24.4	(76)	53	689	(100)	1.5		X	X		
C39	24.4	(76)	53	689	(100)	1.5		X	X		
C40	24.4	(76)	53	689	(100)	1.5		X	X		
C41	24.4	(76)	53	689	(100)	1.5		X	X		
C42	24.4	(76)	53	689	(100)	1.5		X	X		
C43	24.4	(76)	53	689	(100)	1.5		X	X		
C44	24.4	(76)	53	689	(100)	1.5		X	X		
C45	24.4	(76)	53	689	(100)	1.5		X	X		
C46	24.4	(76)	53	689	(100)	1.5		X	X		
C47	24.4	(76)	53	689	(100)	1.5		X	X		
C48	24.4	(76)	53	689	(100)	1.5		X	X		
C49	24.4	(76)	53	689	(100)	1.5		X	X		
C50	24.4	(76)	53	689	(100)	1.5		X	X		

Table 7. Shipping tray integrity test results

Test number	Temperature °C	(°F)	Humidity %	Transfer pressure kPa	(psi)	Metering valve setting	Donor reaction Yes	No	Detonator aligned Yes	No	Remarks
E1	23.9	(75)	50	689	(100)	N/A	X		X		Detonation
E2	23.9	(75)	50	689	(100)	N/A	X		X		Detonation
E3	23.9	(75)	50	345	(50)	N/A	X		X		
E4	23.9	(75)	50	345	(50)	N/A		X		X	Detonator was sideways in pallet
E5	23.9	(75)	50	345	(50)	N/A		X	X		
E6	26.1	(79)	62	345	(50)	N/A		X	X		
E7	26.1	(79)	62	345	(50)	N/A		X		X	Detonator sideways in pallet
E8	26.1	(79)	62	689	(100)	N/A		X		X	Detonator not seated correctly
E9	26.7	(80)	63	689	(100)	N/A		X	X		
E10	26.7	(80)	63	689	(100)	N/A		X		X	Missed hole in pallet
E11	16.1	(61)	50	689	(100)	N/A	X		X		
E12	16.1	(61)	50	621	(90)	N/A	X		X		
E13	16.1	(61)	50	552	(80)	N/A	X		X		
E14	16.1	(61)	50	483	(70)	N/A	X		X		
E15	16.1	(61)	50	414	(60)	N/A	X		X		
E16	16.1	(61)	50	345	(50)	5.0	X		X		Installed metering valve
E17	16.1	(61)	50	345	(50)	4.0	X		X		
E18	16.1	(61)	50	552	(80)	3.0		X	X		
E19	16.1	(61)	50	345	(50)	3.0		X	X		
E20	16.1	(61)	50	345	(50)	3.0		X	X		
E21	16.1	(61)	50	483	(70)	3.0		X	X		
E22	16.1	(61)	50	552	(80)	3.0		X	X		
E23	24.4	(76)	65	621	(90)	3.0		X	X		
E24	24.4	(76)	65	655	(95)	3.0		X	X		
E25	24.4	(76)	65	676	(98)	3.0		X	X		Donor had a dent in it from bouncing out of tray
E26	24.4	(76)	65	689	(100)	3.0	X		X		
E27	24.4	(76)	65	689	(100)	2.0		X	X		
E28	24.4	(76)	65	689	(100)	2.0		X	X		
E29	24.4	(76)	65	689	(100)	2.0		X	X		
E30	24.4	(76)	65	689	(100)	2.0		X	X		
E31	22.2	(72)	65	689	(100)	2.0		X	X		
E32	22.2	(72)	65	689	(100)	2.0		X	X		
E33	22.2	(72)	65	689	(100)	2.0		X	X		
E34	22.2	(72)	65	689	(100)	2.0		X	X		
E35	22.2	(72)	65	689	(100)	2.0		X	X		
E36	22.2	(72)	65	689	(100)	2.0		X	X		
C1	26.7	(80)	40	689	(100)	2.0		X	X		
C2	26.7	(80)	40	689	(100)	2.0		X	X		
C3	26.7	(80)	40	689	(100)	2.0		X	X		
C4	26.7	(80)	40	689	(100)	2.0		X	X		
C5	26.7	(80)	40	689	(100)	2.0		X	X		
C6	26.7	(80)	40	689	(100)	2.0		X	X		
C7	26.7	(80)	40	689	(100)	2.0		X	X		
C8	26.7	(80)	40	689	(100)	2.0		X	X		

Table 7. Shipping tray integrity test results (cont)

Test number	Temperature		Humidity	Transfer pressure		Metering valve setting	Donor reaction		Detonator aligned		Remarks
	°C	(°F)	%	kPa	(psi)		Yes	No	Yes	No	
C9	26.7	(80)	40	689	(100)	2.0		X	X		
C10	26.7	(80)	40	689	(100)	2.0		X	X		
C11	26.7	(80)	40	689	(100)	2.0		X	X		
C12	26.7	(80)	40	689	(100)	2.0		X	X		
C13	26.7	(80)	40	689	(100)	2.0		X	X		
C14	26.7	(80)	40	689	(100)	2.0		X	X		
C15	26.7	(80)	40	689	(100)	2.0		X	X		
C16	26.7	(80)	40	689	(100)	2.0		X	X		
C17	26.7	(80)	40	689	(100)	2.0		X	X		
C18	26.7	(80)	40	689	(100)	2.0		X	X		
C19	26.7	(80)	40	689	(100)	2.0		X	X		
C20	26.7	(80)	40	689	(100)	2.0		X	X		
C21	26.7	(80)	40	689	(100)	2.0		X	X		
C22	26.7	(80)	36	689	(100)	2.0		X	X		
C23	26.7	(80)	36	689	(100)	2.0		X	X		
C24	26.7	(80)	36	689	(100)	2.0		X	X		
C25	26.7	(80)	36	689	(100)	2.0		X	X		
C26	26.7	(80)	36	689	(100)	2.0		X	X		
C27	26.7	(80)	36	689	(100)	2.0		X	X		
C28	26.7	(80)	36	689	(100)	2.0		X	X		
C29	26.7	(80)	36	689	(100)	2.0		X	X		
C30	26.7	(80)	36	689	(100)	2.0		X	X		
C32	26.7	(80)	36	689	(100)	2.0		X	X		
C33	27.8	(82)	35	689	(100)	2.0		X	X		
C34	27.8	(82)	35	689	(100)	2.0		X	X		
C35	27.8	(82)	35	689	(100)	2.0		X	X		
C36	27.8	(82)	35	689	(100)	2.0		X	X		
C37	27.8	(82)	35	689	(100)	2.0		X	X		
C38	27.8	(82)	35	689	(100)	2.0		X	X		
C39	18.3	(65)	68	689	(100)	2.0		X	X		
C40	18.3	(65)	68	689	(100)	2.0		X	X		
C41	18.3	(65)	68	689	(100)	2.0		X	X		
C42	18.3	(65)	68	689	(100)	2.0		X	X		
C43	18.3	(65)	68	689	(100)	2.0		X	X		
C44	18.3	(65)	68	689	(100)	2.0		X	X		
C45	18.3	(65)	68	689	(100)	2.0		X	X		
C46	18.3	(65)	68	689	(100)	2.0		X	X		
C47	18.3	(65)	68	689	(100)	2.0		X	X		
C48	18.3	(65)	68	689	(100)	2.0		X	X		
C49	18.3	(65)	68	689	(100)	2.0		X	X		
C50	18.3	(65)	68	689	(100)	2.0		X	X		

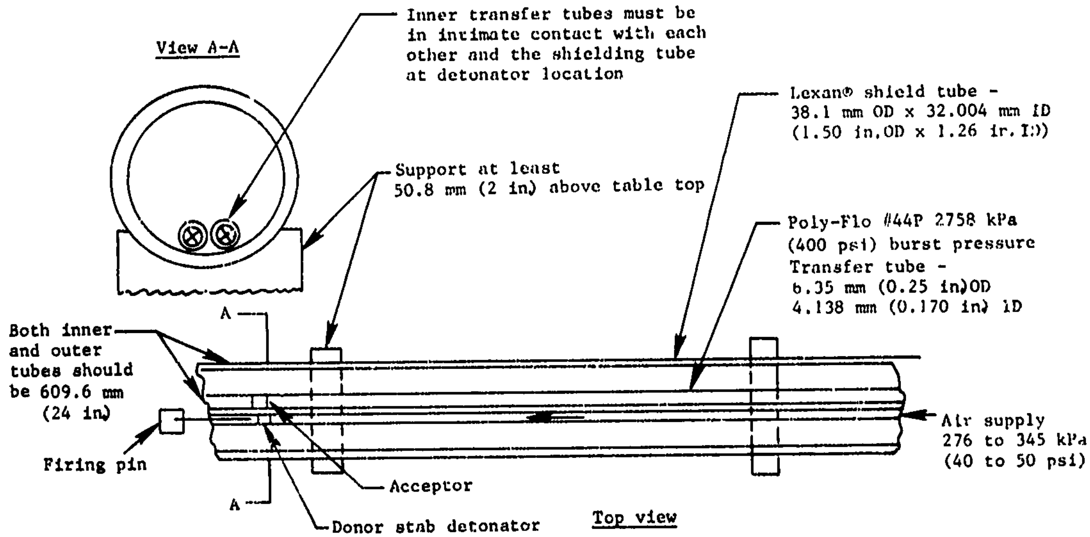

Figure 1. Test setup for input/output transfer tube tests

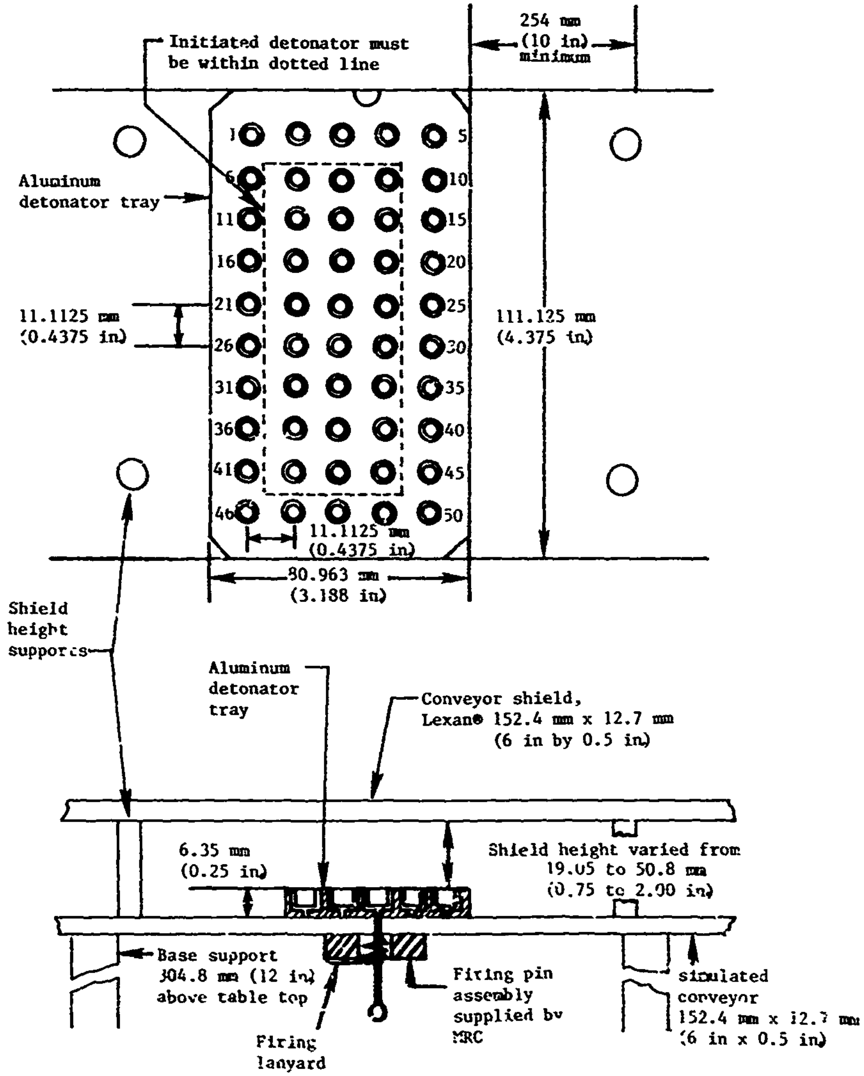

Figure 2. Intra-tray propagation test setup (typical)

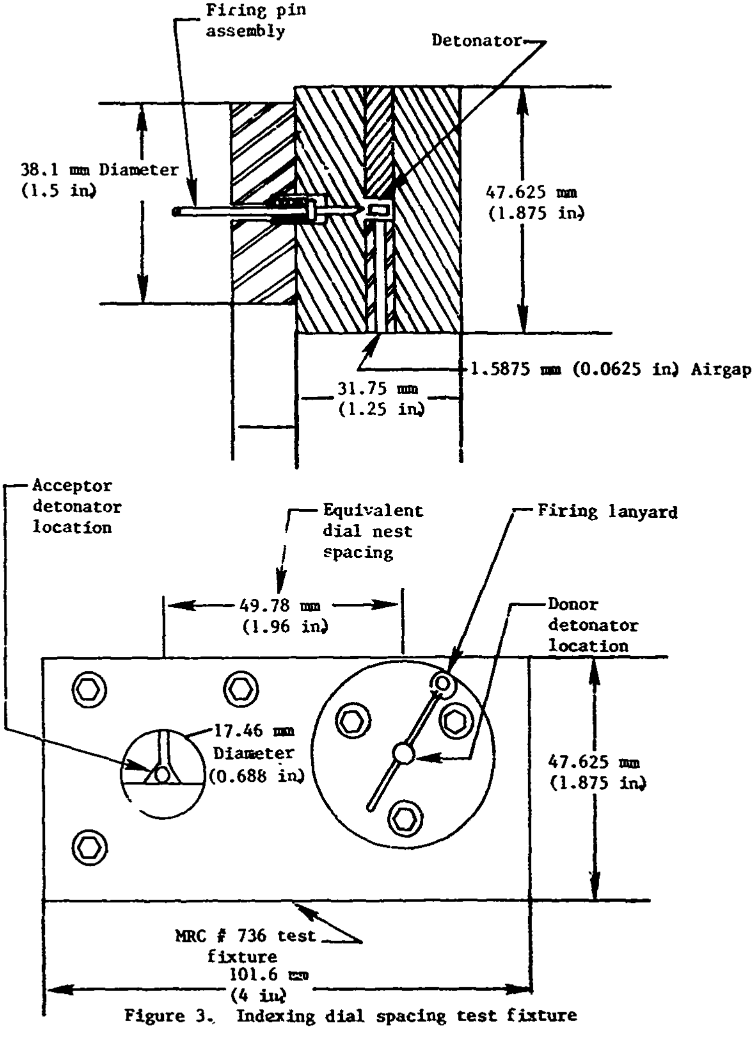

Figure 3. Indexing dial spacing test fixture

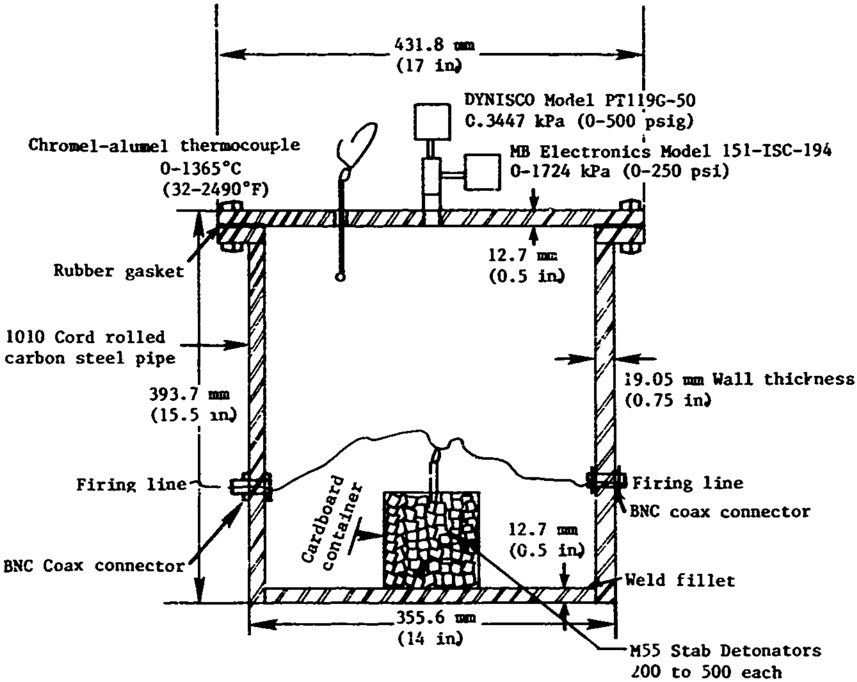

Figure 4. Rejected detonator container

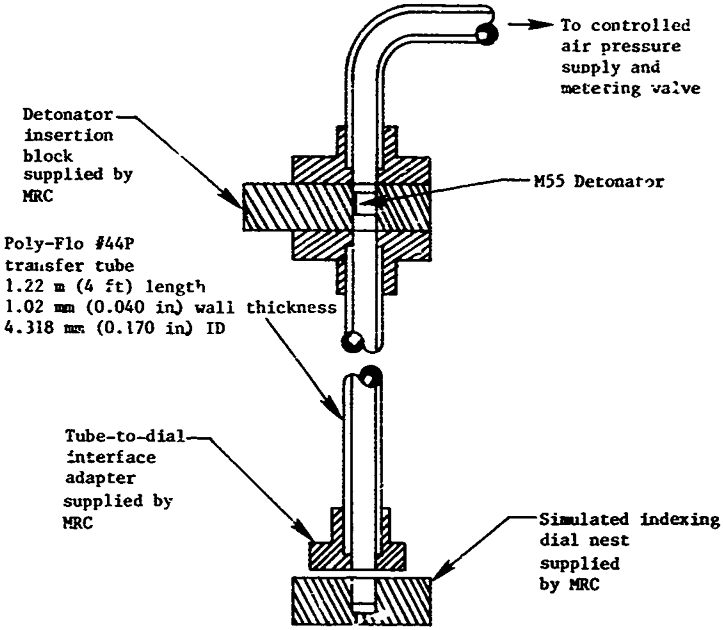

Figure 5. Indexing dial nest integrity test setup

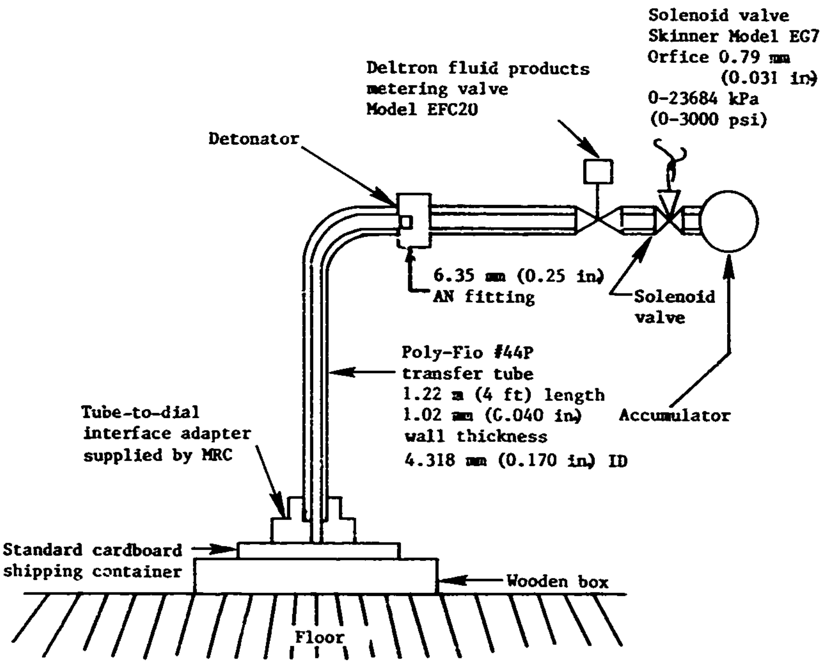

Figure 6. Shipping tray integrity test setup

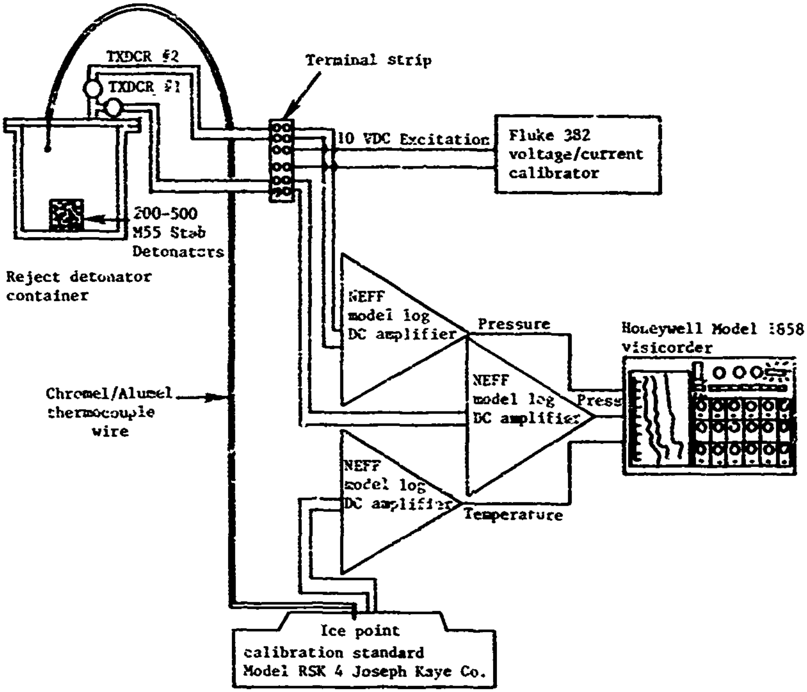

Figure 7. Instrumentation test setup for pressure and temperature measurements

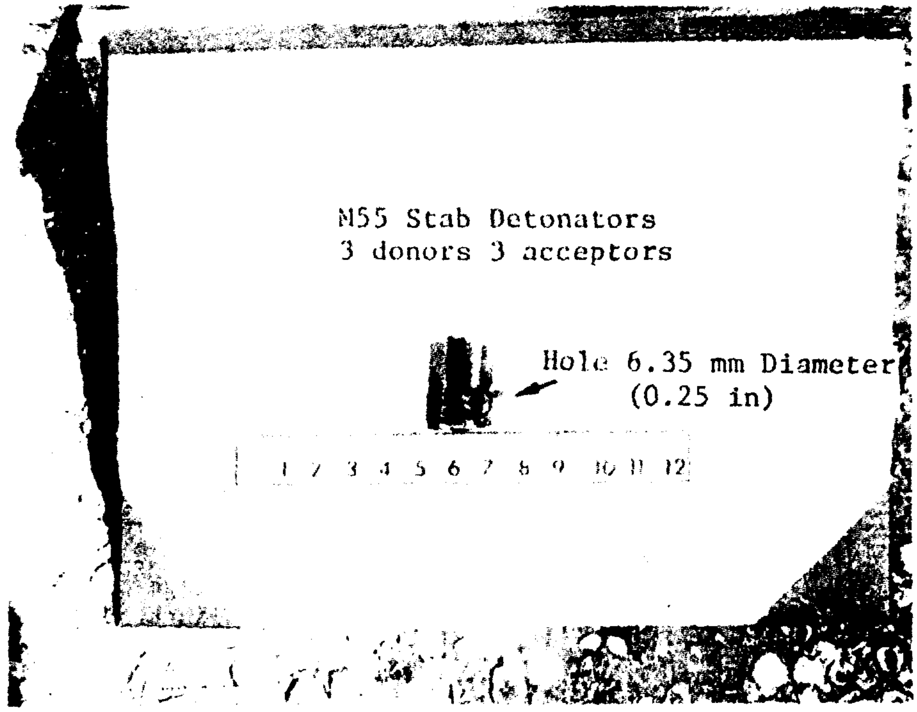

Figure 8. Damage to Lexan® outer shield with 3 donor and 3 acceptor detonators functioning - Input/output transfer test

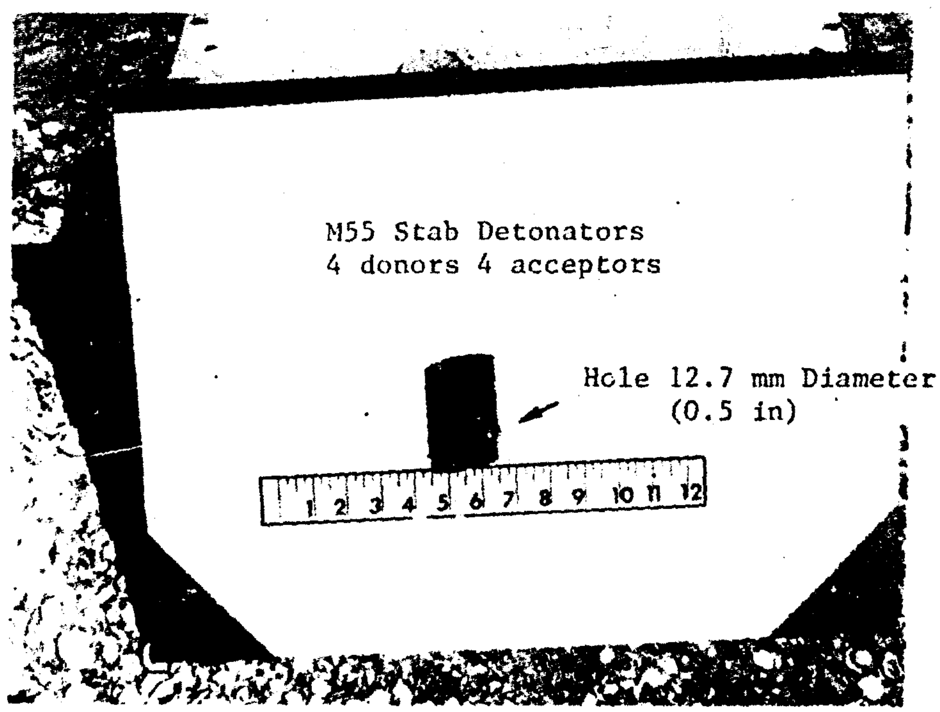

Figure 9. Damage to Lexan® outer shield with 4 donor and 4 acceptor detonators functioning - Input/output transfer test

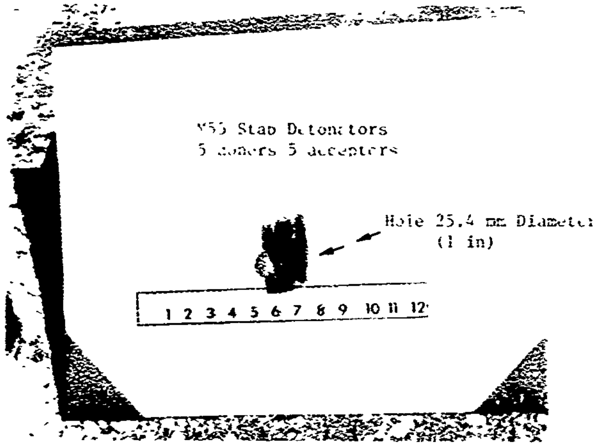

Figure 10. Damage to Lexan® outer shield with 5 donor and 5 acceptor detonators simultaneously initiated - Input/output transfer test

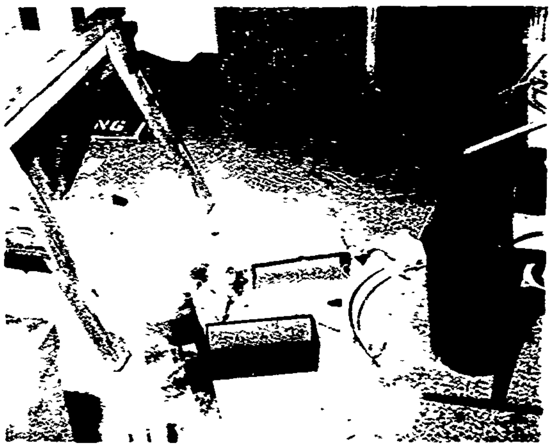

Figure 11. Damage to test area when 50 stab detonators simultaneously initiated during intra-tray propagation tests

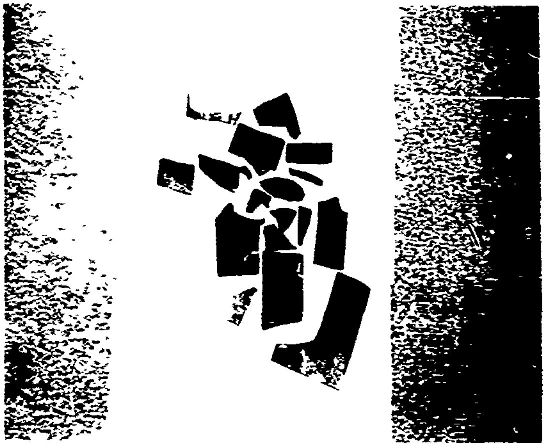

Figure 12. Shattered Lexan® shield when 50 stab detonators simultaneously initiated during the intra-tray propagation tests

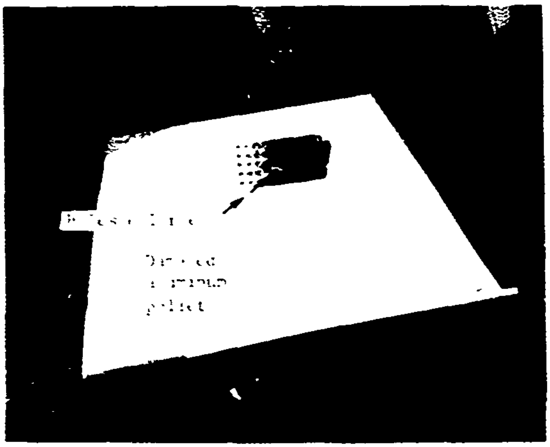

Figure 13. Damage to aluminum pallet when 50 stab detonators simultaneously initiated during the intra-tray propagation tests

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